

EuroTraining develops the Nanoelectronics Training Roadmap

Zsolt Illyefalvi-Vitéz¹, Hervé Fanet²

¹Department of Electronics Technology (ETT)

Budapest University of Technology and Economics (BME)

Goldman t 3., H-1111 Budapest, Hungary; illye@ett.bme.hu

²Laboratoire d'électronique et de technologie de l'information (LETI)

Commissariat à l'Énergie Atomique (CEA)

17, rue des Martyrs, Grenoble Cedex 9, France, F-38054; herve.fanet@cea.fr

Abstract

The ultimate goal of the EuroTraining Project is to enhance European industrial competitiveness in the global marketplace mainly by providing easy access to European training courses and by stimulating the development of new courses in the field of micro- and nanoelectronics. Training and university education roadmaps are being developed to support these activities. The nanoelectronics training roadmap will reach conclusions from the analyses of the needs of industry with a special focus on SMEs; of EU's new Member States; and of the broader public.

1. OBJECTIVES OF THE EUROTRAINING PROJECT

EuroTraining – as one of the five basic services of Europractice – is the European Commission's initiative, which aims to stimulate the wider exploitation of state-of-the-art micro- and nanoelectronics technologies by European industry. The ultimate goal is to enhance European industrial competitiveness in the global marketplace.

EuroTraining has got support from the ICT programme under FP7 for a three year continuation with workpackages shown in Figure 1.

⇒ Students benefit from EuroTraining courses presented via the **EuroTraining Course Directory (ECD)** and **EuroTraining News**.

⇒ Course Providers can freely publicize their courses and include a hyperlink to their own web sites in the **EuroTraining Course Directory**. They can take advantage of the **European Quality Labelling Service** and the exciting new opportunities for course promotion as well.

2. NANO ELECTRONICS TRAINING ROADMAP

A **Training Roadmap** is being developed to identify future training requirements in micro- and nanoelectronics. The objective of the Roadmap is to provide directives for:

⇒ EuroTraining activities in the workpackages,

⇒ influencing training developments and provisions Europe-wide.

Taking into consideration the industrial course requirements, workpackage WP1 focuses on the following types of professional advancement training:

Gap filling, i.e. the stimulation of course providers to provide state-of-the-art training in areas not already covered by the market.

Thematic training: specific training offers dedicated to SMEs.

Train-the-Trainers: specific training offers for the New Member States.



Fig.1: Workpackages of the EuroTraining Project

The Project is offering a two-fold programme addressing both students and course providers.

3. DETERMINERS OF THE TRAINING ROADMAP

3.1. European Commission's policy towards nanotechnology

European Commission's views and recommendations regarding Nanoscience and Nanotechnology have been posted to the EC's Nanotechnology Research portal at the site of <http://ec.europa.eu/nanotechnology/>.

The Communication from the EC "Towards a European Strategy for Nanotechnology" [1] defines nanoscience and nanotechnology which "refer to science and technology at the nanoscale of atoms and molecules, and to the scientific principles and new properties ... for the development of materials and devices with novel functions and performance".

Nanoscience benefits from an **interdisciplinary** or "converging" approach. Accordingly, in EC's policy **nanoelectronics is treated as an inherent part of nanotechnology** as a whole, however electrical and electronics **applications** appear in many of the beneficiary areas, in particular as follows:

⇒ Information technologies, including data storage media and flexible plastic display technologies; in the long-term, the realization of molecular or biomolecular nanoelectronics, spintronics and quantum computing;

⇒ Energy production and storage including low-cost photovoltaic solar cells (e.g. solar "paint") and improved insulation, transport and efficient lighting;

⇒ Materials science developments and surface nano-structuring to impact upon the fabrication of biosensors and molecular electronics devices;

⇒ Manufacturing at the nanoscale, that requires a new interdisciplinary approach along one of the two main routes: the first starts from micro-systems and miniaturizes them ("top-down") and the second builds structures starting at atomic and molecular level ("bottom-up");

⇒ Instrumentation for the study of the properties of matter at the nanoscale.

The Commission calls upon Member States for actions in connection with investing in human resources, to contribute to

(a) Identifying the educational needs of nanotechnology and provide examples of best practice and pilot studies;

(b) Encouraging the definition and implementation of new courses and curricula, teacher training and educational materials for both school and graduate level education;

(c) Integrate complementary skills into post-graduate and life-long training, e.g. entrepreneurship, health and safety issues at work, patenting, "spin-off" mechanisms, communication, etc.

3.2. New instruments in the ERA

On the encouragement of the Commission, **European Technology Platforms (ETPs)** have been established. Technology Platform is a new partnership for building the knowledge society and leveraging knowledge and innovation for growth and employment. ETPs are industry led forums involving main public and private stakeholders (member states, industry, research, finance, public bodies) to address technological and related challenges. In the supporting activities ETPs follow a three-stage process development (Figure 2).



Fig.2: Supporting activities of the ETPs

Nanotechnology related ETPs are as follows:

⇒ **Nanomedicine** for nanotechnology for health: <http://cordis.europa.eu/nanotechnology/nanomedicine.htm>;

⇒ **ENIAC** (<http://cordis.europa.eu/ist/eniac/>) for nano-electronics;

⇒ **SusChem** (Sustainable Chemistry) for nano-materials (<http://www.suschem.org/>);

⇒ **ETPIS**: Industrial Safety for nano-safety (<http://www.industrialsafety-tp.org/>);

⇒ **Innovative Medicine** for the development of new medicines, including nanotechnology approaches (<http://cordis.europa.eu/lifescihealth/innovativemedicines.htm>).

The European Commission established also the **European Institute of Innovation and Technology (EIT)** to contribute to bridging the innovation gap between the EU and its competitors by promoting further **the integration of the three sides of the knowledge triangle** (Figure 3).

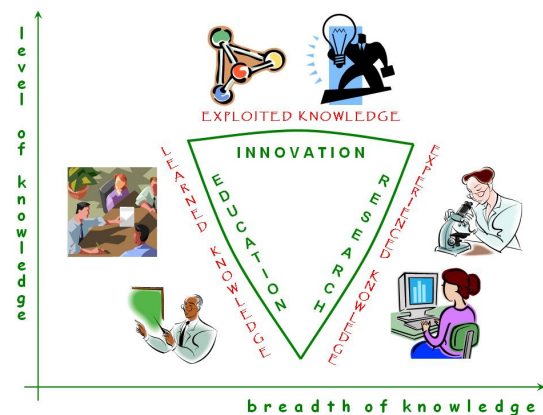


Fig.3: Interdependences of learned, experienced and exploited knowledge

interact efficiently across radically different domains, they need broad knowledge on basic as well as on highly experienced levels (Figure 7).

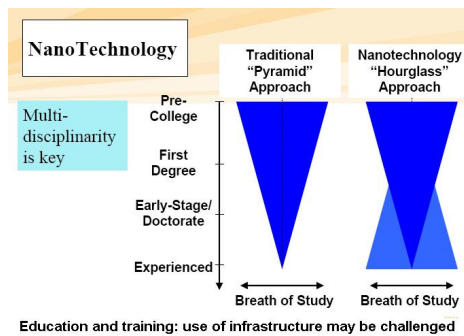


Fig.7: Broad knowledge is required by nanotechnology

3.5. Training activities of funded EU projects

On the basis of course provision needs we can say:

- ⇒ "More Moore" approach suits for specialists to develop design skills;
- ⇒ "More than Moore" courses are needed for engineers to enhance applications;
- ⇒ "Beyond CMOS" training is essential for all people to increase public awareness and the general interest in technical sciences.

Funded EU projects (Table 1) provide perfect training courses for their special areas.

Tab. 1: Electronics oriented EU projects and topics

FP6 Project	Topic of research
NANOCMOS	45 and 32 nm
ESENSE	Beyond 3G
CLEAN	Low power
SPRINT	IP reuse
STIMESI	MEMs and SIPs
NODE	Nanowires applications
SCALA	Quantum computer
SARC	Advanced computer architecture
SHAPES	Distributed architecture
MORE MOORE	Extreme UV lithography
MIMOSA	Microsystems platform for mobiles
MORPHEUS	Reconfigurable
MIAMI	Advanced platform for mobiles

3.6. The worldwide electronics market and industry

Market and industry analyses (Figure 8) also show that training systems to increase **public awareness of nanoscience and nanotechnology** are necessary for the workforce of the services and the electronics production area.

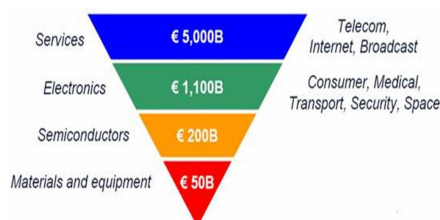


Fig.8: The worldwide electronics market and industry

4. BEST TRAINING PRACTICES AND CONTENTS

4.1. Training Content in Practice

Regarding the nanoelectronics course content, there are much less courses available with more emphases on nanoscience, nanomaterials, nanotechnology, nanomanufacturing and applications, than on theory and design. These professional advancement courses might be suitable for researchers, however for the manufacturing industry, for SMEs and for general purpose in the New Member States course topics should include the followings:

⇒ **Basic issues of nanoelectronics** like:

- design methods and tools (CAD tools, SoC, analogue design, RF, IP re-use and exchange of IP)
- technology issues (Submicron, SOI, SiGe, GaAs, etc.)

- designing with configurable structures such as FPGAs

⇒ **Application issues**, presenting the benefits of nanoelectronics resulted in highly reliable and widely accessible wireless communications & networking services, combined with power saving nanotechnologies in such fields like:

- ambient intelligence,
- nano-scale medical diagnostics and treatment,
- cleaner, safer and more comfortable transport,
- anti-terrorism and security applications, etc.

The course of Prof Göran Wendin, Chalmers University, Sweden, entitled *Nanotechnology for future electronics: "more of Moore" and "beyond Moore"*, with the following abstract is a promising example:

The field has already entered the nanoelectronics era with commercial CMOS transistors for processors and memory having 50-100 nm dimensions. Moore's law suggests that around 2020 essential dimensions may reach the 5-10 nm range. Presently nobody imagines that silicon and CMOS technology will be replaced in the near future, even by 2020. The discussion rather concerns "more of Moore", i.e. how to develop new types of semiconductor devices and architectures that fit into the old framework, and "beyond Moore", i.e. how to develop complementary nanoelectronics that can be integrated on silicon chips to extend the performance. Here e.g. molecular electronics could play a role. Moreover, quantum-effect devices, ballistic devices, quantum computing with superconducting electronic circuits and semiconductor quantum dots are currently intensely investigated. Nanoelectronics is most likely going to be to create interfaces between artificial and biological "computational matter", with potential for truly revolutionary development.

4.2. Advanced Training Methods of Nanoelectronics

The following training methods are used worldwide, particularly in North America, for the education of nanoscience, nanotechnology and nanoelectronics:

- WEB to discover nano: reaching the general public using the Internet
- Nanocity, Nano Truck: reaching the general public by exhibiting scientific tools and results
- Nanoscience module for secondary schools
- Journal of undergraduate research
- REU: Research Experience opportunities for Undergraduates in summer
- Undergraduate academic year research opportunities
- Graduate fellowships
- Research and curriculum development program for teachers
- Seminar series: Frontiers in nanotechnology
- Nano-day: an event for children
- Nanotechnology curriculum development
- International research opportunities
- Miscellaneous educational outreach

Highly advanced nanoelectronics websites are available with list of courses, training schedules and accessible or downloadable short courses. At the first place, the www.NanoED.org Resource Portal should be mentioned (Figure 9). Teachers looking for help with nanoscience curriculum can also find assistance on the NanoEd Resource Portal (Figure 10).

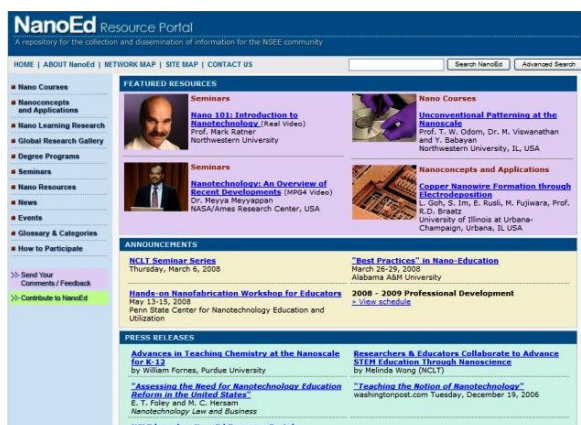


Fig.9: Nanoelectronics course offer on NanoEd

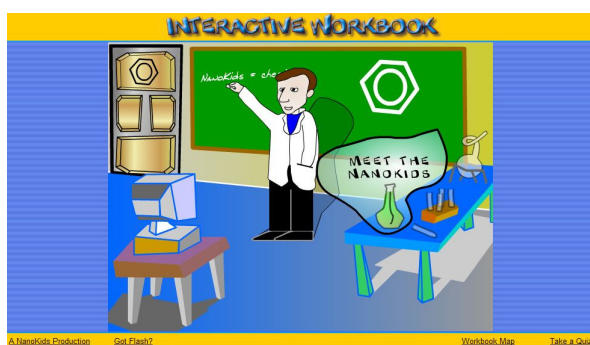


Fig.10: Interactive workbook in the NanoKids™ project

In addition to training offers, the Nanoforum.org website, the European Nanotechnology Gateway contains basic learning materials about nanoscience and nanotechnology (Figure 11).

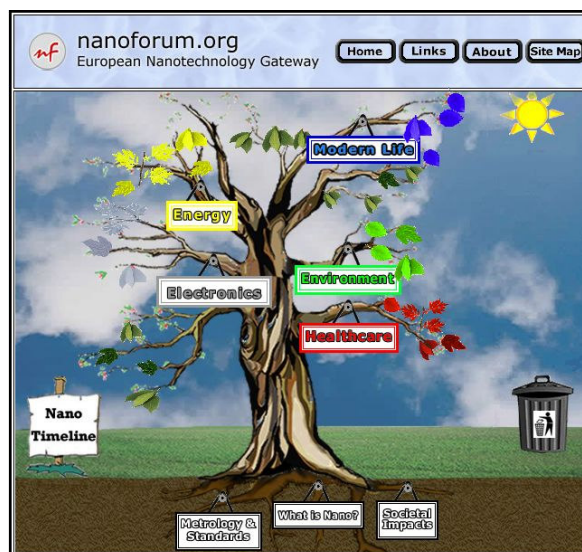


Fig.11: Nanoforum Educational Glossary Tree

A unique German initiative is the Nano-Truck (Figure 12), which is touring Europe – literally. The goal of the project – sponsored by the German Ministry for Education and Research – is to increase public information about nanotech and awareness of the new technology. Or put less subtly, based on the press release, to "demonstrate that nanotechnology is a future technology with immense long-term potential." More information can be found on the website of <http://www.nanotruck.de/en>.

The Nano Truck has an extensive display of posters and exhibits on the principles, applications and prospects of nanotechnology. The truck also provides a mobile world of experience and offers science live to touch on an area of some 60 square meters. The truck is accompanied on its tour of Germany by experienced scientists, who provide firsthand answers to questions from exhibition visitors.



Fig.12: Nano Truck provides mobile nano world experience

5. CONCLUSIONS

5.1. Increase Public Awareness

The **general conclusion** is that training activities should increase **public awareness** of nanoelectronics, considering the following key aspects:

⇒ Improve the training activity and effectiveness of the collaborative research programmes and the Technology Platforms, in particular that of ENIAC;

⇒ Open the research infrastructure for the interested people, in particular teachers and undergraduate students;

⇒ Initiate training programs for secondary school teachers of the natural sciences;

⇒ Establish mobile courses with hands-on experiment possibilities (see a good practice at www.nanotruck.net);

⇒ EC and local governments take measures to increase the number of students in nanoelectronics-related fields.

Course content needs for projects and platforms:

⇒ More Moore: for specialists to develop design skills

⇒ More than Moore: for engineers to enhance applications

Training content needs for EuroTraining stimulated course provision **for industry, SMEs and New Member States:**

⇒ Nanoscience and nanotechnology, including beyond CMOS: for all people to increase public awareness and interest in technical sciences

⇒ Target audience would include all ages and levels (school, graduate, post-graduate); all industries (including SMEs); all countries (including New Member States)

⇒ Special attention should be paid to teachers' training (train-the-trainers); educational materials (use the Internet, course sharing); complementary skills (spin-off, safety).

5.2. Short Course for Industrial Needs

On the basis of the results of an industrial survey, the development and provision of the following short course will be stimulated by EuroTraining.

Nanotechnology for Electronics - Course Syllabus

The content for the proposed course and the approximate time for covering each topic are given below. The total number of contact hours for instruction is 8x45 minutes (6 hours) over one day, which also includes altogether two hours for coffee and lunch breaks. An additional two-hour session for questions and answers can be held on request.

08.30-10.00 Introduction (1,5 hours)

Definitions and theory

Explanation and comparison of the significant nanoelectronics approaches: More Moore; More than Moore and Beyond CMOS

Materials for nanoelectronics: carbon nanotubes, inorganic nanowires and other nano materials vs the miniaturization techniques in the nanoscale of SOI, SiGe, GaAs, etc devices

10.00-10.30 Coffee break

10.30-12.00 Processing techniques, tools and novel devices (1,5 hours)

Top-down and bottom-up processing techniques of nanoelectronics devices

Top-down technology: nanolithography; 3D interconnection technology; low power design methods and CAD tools; reliability, life time, and heat dissipation issues; test technology

Nanotechnology tools for bottom-up technique: electron microscopy, Atomic Force Microscopy (AFM), Scanning Tunneling Microscopy (STM) and other techniques

Novel nanoelectronics devices and architectures

12.00-13.00 Lunch break

13.00-14.30 Nanoelectronics applications (1,5 hours)

Application of nanoscale sensors, field emission, thermoelectric and other nanoelectronics devices

Application of nanoscale devices with more functionality: sensors, devices in biomedical/chemical/other interdisciplinary fields, actuators

Nanoelectronics applications for great diversity: ambient intelligence; nanoscale medical diagnostics and treatment; cleaner, safer and more comfortable transport; anti-terrorism and security applications, etc.

14.30-15.00 Coffee break

15.00-16.30 Practical demonstration and case studies (1,5 hours)

Demonstration of practical works (video), examples, illustrations

Case studies, up-to-date research and development results

Problems and possible solutions (problem solving / discussion)

16.30-18.00 Problem solving discussion on request (max 1,5 hours)

REFERENCES

[1] European Commission: Communication from the Commission: Towards a European Strategy for Nanotechnology, European Communities, 2004; <http://www.cordis.lu/nanotechnology>

[2] Rosalie Zobel (Director ICT "Components & Systems", European Commission): Implementing (part of) the SRA on nanoelectronics for Europe – The ENIAC Joint Undertaking; ENIAC Forum, Budapest, 28 Nov 2007; <http://www.eniac.eu/>

[3] Vision 2020 – Nanoelectronics at the centre of change: A far-sighted strategy for Europe; Report of the High Level Group - June 2004, EUR 21149; <http://www.eniac.eu/>

[4] Dirk Beernaert (EC DG-INFSO, Head, Nanoelectronics Unit): Implementation of a European Strategic Research Agenda (SRA), Research and Competitiveness of Nanoelectronics Industry, Electronics Regulatory Group meeting, Dec 6, 2007, Brussels; http://cordis.europa.eu/fp7/ict/nanoelectronics/documents_en.html